

## SYSTEM ARCHITECTURE FOR MANAGING HYDROGEN LEAKS INTO FLUID CIRCUITS OF FUEL CELL SYSTEMS

### FIELD OF THE INVENTION

**[0001]** The present invention relates to fuel cell systems, and more particularly to managing hydrogen leaks into fluid circuits of fuel cell systems.

### BACKGROUND OF THE INVENTION

**[0002]** Fuel cell systems include a fuel cell stack that produces electrical energy based on a reaction between a hydrogen-based feed gas (e.g., pure hydrogen or a hydrogen reformate) and an oxidant feed gas (e.g., pure oxygen or oxygen-containing air). The hydrogen-based feed gas and oxidant feed gas are supplied to the fuel cell stack at appropriate operating conditions (i.e., temperature and pressure) for reacting therein. The proper conditioning of the feed gases is achieved by other components of the fuel cell stack to provide the proper operating conditions.

**[0003]** The fuel cell system includes multiple cooling circuits for cooling various components. At least one cooling circuit is in fluid communication with the fuel cell stack to regulate the temperature of the fuel cell stack at a desired operating temperature. Gaskets within the fuel cell stack seal the cooling circuits from the feed gases flowing through the fuel cell stack. It is conceivable that the hydrogen-based feed gas could leak into one of the cooling circuits.

## SUMMARY OF THE INVENTION

[0004] Accordingly, the present invention provides a pressure management system that balances pressure between first and second fluid circuits of a fuel cell system. The pressure management system includes a first fluid reservoir associated with the first fluid circuit and a second fluid reservoir associated with the second fluid circuit. The second fluid reservoir is in fluid communication with the first fluid reservoir. A fluid is transferred from the first fluid reservoir to the second fluid reservoir during an over-pressure condition within the first fluid circuit.

[0005] In other features, a fluid passage enables the fluid communication between the first and second fluid reservoirs. A first fluid retained within the first fluid reservoir flows into the second fluid reservoir during the over-pressure condition.

[0006] In still other features, a first relief mechanism is disposed between the first and second fluid reservoirs and selectively enables fluid communication between the first and second fluid reservoirs. When a first pressure is achieved within the first fluid reservoir, the fluid flows through the first relief mechanism to the second fluid reservoir to relieve the first pressure.

[0007] In yet other features, a second relief mechanism is disposed between the first and second fluid reservoirs and selectively enables fluid communication between the first and second fluid reservoirs. When a second pressure is achieved within the second fluid reservoir, the fluid flows through the second relief mechanism to the first fluid reservoir to relieve the second pressure.

[0008] In yet other features, a relief mechanism is in fluid communication with the first fluid reservoir. The relief mechanism exhausts the fluid to atmosphere during a critical pressure condition.

[0009] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0011] Figure 1 is a schematic illustration of a fuel cell system including multiple fluid circuits according to the present invention;

[0012] Figure 2 is a schematic illustration of a leak management system managing a first leak condition;

[0013] Figure 3 is a schematic illustration of the leak management system of Figure 2 managing a second leak condition; and

[0014] Figure 4 is a schematic illustration of an alternative leak management system managing the first leak condition.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0016] Referring now to Figure 1, a fuel cell system 10 is shown. The fuel cell system 10 includes a fuel cell stack 12, a hydrogen supply unit 14 and an oxygen supply unit 16. The hydrogen supply unit 14 supplies a hydrogen feed gas to the fuel cell stack 12. When the hydrogen feed gas is hydrogen, the hydrogen supply unit 14 includes a storage vessel and the associated plumbing and controls (not shown) to supply the hydrogen to the fuel cell stack 12. When the hydrogen feed gas is a hydrogen reformate, the hydrogen supply unit 14 includes a storage vessel for storing a base fuel and the components, plumbing and controls (not shown) required to dissociate the base fuel into the hydrogen containing feed gas and to supply the hydrogen feed gas to the fuel cell stack 12. The oxidant feed gas is generally provided as oxygen-rich air. Thus, the oxygen supply unit 16 generally includes a compressor, plumbing and controls (not shown) required to supply the oxidant feed gas to the fuel cell stack 12. The fuel cell stack 12 generates electrical energy used to power an electrical load or loads 18. The electrical load(s) 18 can include an electric motor, lights, heaters or any other type of electrically powered components.

[0017] The fuel cell system 10 further includes first and second fluid circuits 20,22, respectively, interconnected by a leak management system 24. The first fluid circuit 20 is in fluid communication with the fuel cell stack 12 to

regulate a temperature of the fuel cell stack 12. The first fluid circuit 20 includes a pump 26, a heat exchanger 28 and a fluid reservoir 30. Fluid is pumped through the fuel cell stack 12 where it is in heat exchange communication with components of the fuel cell stack 12.

**[0018]** The fluid flowing through the fuel cell stack 12 regulates the temperature of the components of the fuel cell stack 12. In a cooling mode, the fluid draws heat from the components to cool the fuel cell stack 12. In a heating mode, the components draw heat from the fluid to heat the fuel cell stack 12. The fluid exits the fuel cell stack 12 and flows through the heat exchanger 28 where it is in heat exchange relationship with ambient air. In the cooling mode, heat from the fluid is dissipated to the ambient air and in the heating mode, the fluid draws heat from the ambient air. The fluid flows to the fluid reservoir 30 from which, it is again pumped through the first fluid circuit 20 by the pump 26.

**[0019]** The second fluid circuit 22 is in fluid communication with the at least one or more of the electrical loads 18 to regulate a temperature thereof. The second fluid circuit 22 includes a pump 32, a heat exchanger 34 and a fluid reservoir 36. Fluid is pumped through the electrical load(s) 18 where it is in heat exchange communication with the electrical load(s) 18. In a cooling mode, the fluid draws heat from the electrical load(s) 18 to cool the electrical load(s) 18. In a heating mode, the electrical load(s) 18 draw heat from the fluid to heat the electrical load(s) 18. The fluid exits the electrical load(s) 18 and flows through the heat exchanger 34 where it is in heat exchange relationship with ambient air. In the cooling mode, heat from the fluid is dissipated to the ambient air and in the

heating mode, the fluid draws heat from the ambient air. The fluid flows to the fluid reservoir 36 from which, it is again pumped through the second fluid circuit 22 by the pump 32.

**[0020]** A controller 38 is in communication with the various components of the fuel cell system 10 to monitor and regulate operation of the fuel cell system 10. More particularly, the controller 38 communicates with the hydrogen supply unit 14 and the oxygen supply unit 16 to control the supply of hydrogen and oxygen to the fuel cell stack 12. The controller 38 is also in communication with the fuel cell stack 12 to monitor operating characteristics such as, but not limited to, temperature and pressure within the fuel cell stack 12. The controller 38 communicates with the electrical load(s) 18 to control operation thereof. The controller 38 further communicates with the first and second fluid circuits 20,22 to regulate temperatures of the fuel cell stack 12 and electrical load(s) 18, respectively.

**[0021]** As the fluid flowing through the first fluid circuit 20 flows through the fuel cell stack 12, it is often separated from the hydrogen feed gas by sealing gaskets (not shown). Because the sealing gaskets do not always provide a perfect seal, high pressure hydrogen feed gas can leak into the fluid flowing through the first fluid circuit 20. Similarly, the fluid flowing through the second fluid circuit 22 can flow through other components and/or electrical load(s) 18 that also have the hydrogen feed gas flowing therethrough. Therefore, it is possible that the hydrogen feed gas can leak into the fluid flowing through the second fluid circuit 22.

[0022] Referring now to Figures 2 and 3, operation of the leak management system 24 operating in first and second leak conditions, respectively, will be described in detail. Generally, the leak management system 24 of Figures 2 and 3 is implemented in configurations where there is potential for the hydrogen feed gas to leak into the fluid in both the first and second fluid circuits 20,22. The reservoir 30 of the first fluid circuit 20 is in fluid communication with the reservoir 36 of the second fluid circuit 22 through first and second release mechanisms 40,42, respectively, serially disposed along a fluid conduit 44. A pressure sensor 46 is disposed between the first release mechanism 40 and the reservoir 30 and is in electrical communication with the controller 38. A safety mechanism 48 is in fluid communication with the fluid conduit 44 between the first and second release mechanisms 40,42.

[0023] The first and second release mechanisms 40,42 and the safety mechanism 48 are generally of a similar construction. Therefore, a generic mechanism will be described in detail. Components of the first and second release mechanisms 40,42 and the safety mechanism 48 will be identified using like reference numbers as those used to indicate components of the generic mechanism. The mechanism 40,42,48 includes a pressure relief valve 50 having an inlet and an outlet 52,54. The pressure relief valve 50 includes a pressure setting. A pilot conduit 56 is in fluid communication with the pressure relief valve 56. As the fluid pressure builds at the inlet 52, the pilot conduit 56 applies the pressure to the pressure relief valve 50. Once the pressure achieves the pressure setting, the pressure relief valve 50 opens to vent the fluid through the

pressure relief valve 50 and the outlet 54. A one-way valve 58 enables selective fluid flow from the outlet 54 to the inlet 52. More particularly, if the fluid pressure in the inlet 52 is higher than the fluid pressure in the outlet 54, the one-way valve 58 remains closed to prohibit fluid communication from the inlet 52 to the outlet 54. If the fluid pressure in the outlet 54 is higher than the fluid pressure in the inlet 52, the one-way valve 58 opens to enable fluid flow from the outlet 54 to the inlet 52.

**[0024]** With particular reference to Figure 2, the leak management system 24 is illustrated experiencing a first leak condition. During the first leak condition, hydrogen feed gas leaks into the first fluid circuit 20. The hydrogen feed gas leak results in a pressure increase within the first fluid circuit 20 including the fluid reservoir 30. If the hydrogen leak persists, the pressure increases until the pressure at the inlet 52 of the first release mechanism 40 becomes greater than the pressure setting ( $P_1$ ) of the first release mechanism 40. When the inlet pressure surpasses  $P_1$ , the pressure relief valve 50 opens enabling fluid flow therethrough. The fluid flow from the first release mechanism 40 increases the fluid pressure within the fluid conduit 44. If the fluid pressure within the fluid conduit 44 is greater than the fluid pressure within the inlet 52 of the second release mechanism 42, fluid flow is enabled into the reservoir 36 of the second fluid circuit 22 through the one-way valve 58. In this manner, a pressure balance is achieved and the pressure increase is shared between the first and second fluid circuits 20,22. Fluid flow between the fluid reservoirs 30,36 during the first leak condition is indicated by the arrows of Figure 2.

**[0025]** With particular reference to Figure 3, the leak management system 24 is illustrated experiencing a second leak condition. During the second leak condition, hydrogen feed gas leaks into the second fluid circuit 22. The hydrogen feed gas leak results in a pressure increase within the second fluid circuit 22 including the fluid reservoir 36. If the hydrogen leak persists, the pressure increases until the pressure at the inlet 52 of the second release mechanism 42 becomes greater than the pressure setting ( $P_2$ ) of the second release mechanism 42. When the inlet pressure surpasses  $P_2$ , the pressure relief valve 50 opens enabling fluid flow therethrough. The fluid flow from the second release mechanism 42 increases the fluid pressure within the fluid conduit 44. If the fluid pressure within the fluid conduit 44 is greater than the fluid pressure within the inlet 52 of the first release mechanism 40, fluid flow is enabled into the reservoir 30 of the first fluid circuit 20 through the one-way valve 58. In this manner, a pressure balance is achieved and the pressure increase is shared between the first and second fluid circuits 20,22. Fluid flow between the fluid reservoirs 30,36 during the second leak condition is indicated by the arrows of Figure 3.

**[0026]** Referring now to both Figures 2 and 3, the safety mechanism 48 functions to prevent an over-pressure event. An over-pressure event in either the first or second fluid circuits 20,22 could result in damage to the components of the fluid circuits. As the fluid pressure continues to increase within the leak management system 24 a shut-down threshold may be achieved. More particularly, the pressure sensor 46 monitors the overall pressure in the leak

management system 24. When the pressure achieves the shut-down threshold the controller 38 shuts down the fuel cell system 10. It should be noted that the pressure settings  $P_1$  and  $P_2$  of the first and second release mechanisms 40,42, respectively, are lower than the shut-down threshold.

**[0027]** Although the fuel cell system 10 shuts-down it is conceivable that the pressure within the leak management system 24 can increase. In such a situation, the safety mechanism 48 enables pressure relief to the atmosphere if the pressure achieves a vent threshold. More particularly, when the pressure surpasses the pressure setting ( $P_3$ ) of the pressure relief valve 50 of the safety mechanism 48, the pressure relief valve 50 opens to vent fluid pressure to the atmosphere. The pressure settings  $P_1$  and  $P_2$  of the first and second release mechanisms 40,42, respectively, are lower than the pressure setting  $P_3$  of the safety mechanism 48.

**[0028]** A hydrogen sensor 60 can be included at or within the proximity of the outlet 54 of the safety mechanism 60. The hydrogen sensor 60 generates a signal indicative of the hydrogen content of the atmosphere surrounding the safety mechanism 48. The controller 38 monitors the hydrogen content signal. If the hydrogen content signal achieves a content threshold, the controller 38 issues an alert to an operator. The alert can be a visual alert, audible alert or both a visual and audible alert.

**[0029]** It is anticipated that the leak management system 24 can be incorporated into individual or common components of the fluid reservoirs 30,36. More particularly, the first release mechanism 40 can be integrated into a filler

cap or cover (not shown) of the fluid reservoir 30 of the first fluid circuit 20. Similarly, the second release mechanism 42 can be integrated into a filler cap or cover (not shown) of the fluid reservoir 36 of the second fluid circuit 22. Alternatively, the first and second release mechanisms 40,42, as well as the safety mechanism 48, can be integrated into a common reservoir cover associated with both fluid reservoirs 30,36.

**[0030]** Referring now to Figure 4, an alternative leak management system 24' is illustrated. The leak management system 24' is generally implemented between the first and second fluid circuits 20,22 where only one fluid circuit is in communication with a hydrogen feed gas source. In the configuration of Figure 4, the first fluid circuit 20 is in communication with the hydrogen feed gas source (e.g., the fuel cell stack 12). The leak management system 24' includes a tube 62 that enables fluid communication between the fluid reservoir 30 of the first fluid circuit 20 and the fluid reservoir 36 of the second fluid circuit 22. The tube 62 is connected to the fluid reservoir 30 of the first fluid circuit 30 at a point below the fluid level within the fluid reservoir 30. The tube 62 is connected to the fluid reservoir 36 of the second fluid circuit 22 at a point above the fluid level of the fluid reservoir 36. The leak management system 24 further includes a safety mechanism 48' in fluid communication with the fluid reservoir 36 of the second fluid circuit 33 and a pressure sensor 46' disposed between the fluid reservoir 36 and the safety mechanism 48'.

**[0031]** In the event of a hydrogen feed gas leak into the fluid circulating through the first fluid circuit 20, the pressure within the first fluid circuit 20

increases. As the pressure within the first fluid circuit increases 20 fluid from the fluid reservoir 30 of the first fluid circuit 20 flows into the fluid reservoir 36 of the second fluid circuit 22 through the tube 62. In this manner, the pressure increase within the first fluid circuit 20 is shared with the second fluid circuit 22. If the hydrogen leak persists, the pressure will increase until achieving the shut-down threshold as monitored by the pressure sensor 46'. When the pressure achieves the shut-down threshold the controller 38 shuts down the fuel cell system 10. It should be noted that the pressure setting  $P_3$  of the safety mechanism 48 is greater than the shut-down threshold.

**[0032]** As similarly described above for the leak management system 24, a hydrogen sensor 60' can be included at or near the outlet 54 of the safety mechanism 48'. The hydrogen sensor 60' generates a signal indicative of the hydrogen content of the atmosphere surrounding the safety mechanism 48'. The controller 38 monitors the hydrogen content signal. If the hydrogen content signal achieves a content threshold, the controller 38 issues an alert to an operator. The alert can be a visual alert, audible alert or both a visual and audible alert.

**[0033]** It is anticipated that the leak management system 24' can be incorporated into individual or common components of the fluid reservoirs 30,36. More particularly, the safety mechanism 48' can be integrated into a filler cap or cover (not shown) of the fluid reservoir 36 of the second fluid circuit 22. Similarly, the safety mechanism 48' can be integrated into a common reservoir cover

associated with both fluid reservoirs 30,36. The tube 62 can be formed as a passage through a common wall that separates the fluid reservoirs 30,36.

**[0034]** The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.